SELF-SEALED VERTICAL NANOPOROUS JUNCTIONS FOR INTEGRATING VARIOUS NANO-MATERIALS IN PDMS MICROFLUIDIC SYSTEM

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ABSTRACT

We developed a simple integration method of polymeric nanostructure in a poly-dimethylsiloxane (PDMS)-based microfluidic channel. The Nafion polymer or charged particle creased by infiltrating solution between the gaps created by mechanical cutting, without any photolithography or etching processes. The PDMS can seal itself with the heterogeneous polymeric nanoporous material between PDMS/PDMS gap due to its flexibility. Thus, one can easily integrate nanoporous-junction into PDMS microchip in a leak-free manner with excellent repeatability.

KEYWORDS: Nanojunction, Polydimethylsiloxane, Integration, Self-sealed

INTRODUCTION

Compared with microfluidic systems, nanofluidic channels exhibit unique properties such as concentration polarization and ion rectification due to electrical double layer overlap. Recently, polymeric materials such as PDMS and PMMA have become an appropriate material for the disposable micro- and nano-fluidic device due to straightforward fabrication processes and low cost. Various methods, including the junction gap breakdown [1] and cracking of oxidized PDMS [2] have been reported for building nanofluidic systems in PDMS substrates. These techniques create nanostructures at the interface between PDMS and cover substrates, therefore nanofluidic junctions are sequestered at the corner of the microchannel and the coupling between the microchannel and the nanojunction is poor. Here, we are reporting a novel technique that can be used to integrate polymeric junctions with microfluidic channel with a good fluidic coupling. We built a nanofluidic molecular concentrator using the technique with the superior repeatability and ease of fabrication. The key to the technique is the reliable sealing of polymeric materials within the gap of PDMS, and the flexibility of PDMS helps to maintain a leak-free junction. This could be a generic method for integration of polymeric junctions (gels, nanoparticles, microparticles) in a PDMS microfluidic devices, without the need for complex chemistry and/ or fabrication processes.

EXPERIMENTAL

Figure 1 describes the fabrication processes. PDMS microchannels can be obtained from the standard PDMS chip fabrication processes (Figure 1(a)). We mechanically cut across the microchannels using conventional razor blades for guiding porous material infiltration after punching sample loading holes (Figure 1(b)). Once the gap was created, PDMS tends to restore its inherent geometric
structure due to its flexibility. By bending the chip, the gap was opened and a drop of 1.5 μL Nafion 117 solution (Fluka) or microbead solution was put on the edge of the gap (Figure 1(c)). Then the solution can immediately fill both the gap and a portion of microchannels by capillary forces. After 10 minutes of curing at 95°C, solvents would evaporate. The elastic nature of PDMS seals the nanoporous junction tightly between the PDMS gap without any (covalent) chemical bonding between PDMS and porous materials. Any remaining material on the top of the PDMS surface and inside microchannel can be removed at once by taping (Figure 1(d)). Finally, glass plate can be bonded on top of the device (Figure 1(e)). The microscope image of fabricated nanoporous-junctions and cooperating microchannels were shown in Figure 2(a) and the cross-sectional SEM image of nanoporous-junctions was given Figure 2(b). This allows one to integrate nanoporous-junction into PDMS microchip in a leak-free manner with excellent repeatability. In addition, vertical nanojunctions are better coupled with the microchannel, allows efficient operations. [3]

Figure 1. Schematics of fabrication processes.

Figure 2. (a) Microscope image and (b) SEM image of cross-section (A-A’).

RESULTS AND DISCUSSION

The DC ion current through the nanoporous-junction can be an excellent indicator for testing reliability and repeatability. The current was proportional to the applied voltage and showed an excellent linearity from randomly selected microchips. As a
practical example, we demonstrated nanofluidic preconcentration [4] of BODIPY dye and proteins (β-phycoerythrin) using the device (Figure 3(a), 3(b)). Because the polymeric junction spans across the entire microchannel height, the preconcentration was achieved with high pressure field or even in large channels, with the dimension of 1000μm width × 100μm depth (Figure 3(c)) which has never been demonstrated before. Microbeads (D=2μm) were used to create the nanojunctions and the preconcentration of FITC dye was achieved as shown in Figure 3(d).

![Graphs showing fluorescence intensity over time for BODIPY dye (a) and β-PE proteins (b).](image)

![Images showing preconcentration of FITC dye using microbead packed nanojunctions.](image)

**Figure 3.** Preconcentration factors of (a) BODIPY dye molecules and (b) β-PE proteins. Ion preconcentration in (c) semi-macrochannels and (d) using microbead packed nanojunctions.

**CONCLUSIONS**

This method could be a simple but generic method for integrating various polymeric and other nanomaterials within the PDMS microfluidic channels. With the aid of the presenting method, we can lower the barrier that has blocked novel nanofluidic researches.

**ACKNOWLEDGEMENTS**

This work was mainly supported by NIH (EB005743, CA119402).

**REFERENCES**